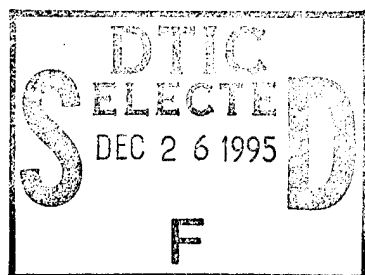




The Interactive Multisensor Analysis Training (IMAT) System: An Evaluation in Operator and Tactician Training



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13. ABSTRACT (Maximum 200 words) The Interactive Multisensor Analysis Training (IMAT) system was developed to address post Cold War ASW training requirements. It is designed to teach the complex conceptual knowledge and cognitive and procedural skills required to reason about the interrelationships among the operating modes of target submarines, the environmental variables that affect sound transmission, and the sensor systems used for detection and tracking. This effort evaluated the application of the IMAT system in the Sonar Technician Surface (STG) "A" school and the Fleet Aviation Specialized Operations Training Group Pacific Tactical Training Course (TTC) at Barbers Point. The results showed that (1) research on cognition and instruction and technological advances in displaying complex information can be integrated and applied in real world training to produce substantial gains in performance and student motivation, (2) the IMAT system achieved its intended design goals by effectively teaching complex knowledge and cognitive skills, (3) the IMAT system emphasis on adhering to the principles of high quality instructional design, especially practice opportunities, contributed significantly to the observed performance improvements, and (4) IMAT can accelerate the development of expertise in tactical oceanography and decision making.					
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Foreword

The evaluations of the Sonar Technician Surface (STG) Class "A" School and the Fleet Aviation Specialized Operations Training Group Pacific Tactical Training Course (TTC) were conducted under the 6.3 Manpower, Personnel, and Training Advanced Technical Development Program Element 0603707N (Work Unit 0603707N.L2335.IM001). The goal of this study was to evaluate the effectiveness of the Interactive Multisensor Analysis Training (IMAT) System in two operational training environments.

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Summary

Problem and Background

The challenges facing Antisubmarine Warfare (ASW) training in the closing years of this decade are greater than at any time since the early days of World War II. Conditions since the end of the Cold War, and those expected throughout the next decade, impose additional complexity on maintaining our ASW superiority. Russian nuclear submarine technology continues to improve and advanced submarines continue to be built and delivered to their fleet. Concurrently, the proliferation of improved diesel submarine technology to many Third World nations requires that our ASW forces also be capable of conducting operations in the vastly different littoral regions.

The training challenge is two-fold: (1) retaining the capability to detect and prosecute nuclear submarines, and (2) expanding our current capability against diesel submarines of the Third World. When coupled with dramatic reductions in ASW training resources, including at-sea training, this historic change compels the development of training for skills learned previously on-the-job and for skills required in new environments for both sensor operators and tacticians.

The Interactive Multisensor Analysis Training (IMAT) system was developed to address post Cold War ASW training requirements. Specifically, IMAT is designed to teach the complex conceptual knowledge and cognitive and procedural skills required to reason about the interrelationships among the operating modes of target submarines, the environmental variables that affect sound transmission, and the sensor systems used for detection and localization. In addition, IMAT provides extensive training on submarine acoustics and interpretation of sensor system data. The IMAT approach to training is based on recent advances in cognitive psychology and instructional technology. It combines cognitive, analytic, and curriculum design technology with advanced computer-based graphics and programming technology to present state-of-the-art training.

Objectives

The objectives of this effort are (1) to evaluate the application of the IMAT system in the Sonar Technician Surface (STG) "A" school with respect to performance on factual, comprehension, and cognitive skill test items, student motivation, and instructional design; (2) to compare student performance on STG "A" IMAT lessons with student performance on comparable Aviation Systems Warfare Operator (AW) A school IMAT lessons; (3) to evaluate application of the IMAT system in the Fleet Aviation Specialized Operations Training Group Pacific Tactical Training Course (TTC) at Barbers Point; and (4) to compare graduates of the IMAT TTC with qualified fleet tactical officers and pilots on tests of knowledge of acoustical oceanography and tactical problem solving.

Method

The STG "A" IMAT application was evaluated on (1) student performance on three types of end of unit test items (fact items, comprehension items, and cognitive skill items), (2) student motivation, and (3) quality of instructional design. Seventy one STG students trained with the IMAT system were compared with 90 STG students trained with the standard instruction used in

the "A" school prior to the introduction of IMAT, and with 46 students from the AW "A" School who had also been trained with the IMAT system.

For the TTC evaluation, 59 students were administered a paper and pencil test that included both knowledge items and scenario based cognitive skills items. They were tested upon entering the school and after completing the course in a standard pre-post design. The scores of the TTC graduates were also compared with the performance of 21 qualified fleet tacticians and pilots on the same testing instrument.

Results

The STG IMAT students scored higher on all item types than the STG Standard Instruction students. Further, the instructional design analysis showed that instructional quality was superior in the STG IMAT lessons. Unfortunately, the motivation data for the STG Standard Instruction students was either lost or not collected. However, motivation for the STG IMAT students was high and compared favorably to previous motivation data for AW IMAT students.

AW IMAT students scored higher on all item types than the STG IMAT and STG Standard Instruction students. Again, the instructional design analysis showed that the AW IMAT instruction was higher in overall quality than the materials for the other two groups. Also, both the STG and AW IMAT groups scored relatively better on cognitive skill and comprehension items compared to fact items than STG Standard Instruction students.

The findings for the TTC course evaluation showed that TTC students had significant gains from pretest to posttest for knowledge and scenario test items. Further, in the comparison with qualified fleet personnel, TTC graduates scored higher than the qualified fleet personnel on both scenario and knowledge items.

Conclusions

Several conclusions can be drawn from this study. First, the IMAT approach to training, based on computer-generated dynamic displays and instructional design and delivery strategies designed to enhance cognition, produces substantial gains in performance. This is especially true for the explicit IMAT goal of teaching complex knowledge and cognitive skills. Second, the IMAT system emphasis on adhering to the principles of high quality instructional design was supported in the instructional design analyses. The differences in design quality among the STG Standard Instruction, STG IMAT, and AW IMAT groups undoubtedly contributed to the observed performance differences. Finally, the TTC findings show that IMAT can bring course graduates up to the level of fleet qualified personnel on both fact and scenario tests. Overall, the results of the STG and TTC implementations show that IMAT is a highly effective training system that offers a viable solution for many of the training requirements and challenges faced in the post cold war world.

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Introduction

Problem and Background

The challenges facing Antisubmarine Warfare (ASW) training in the closing years of this decade are greater than at any time since the early days of World War II. During the Cold War, ASW mission requirements (and the training designed to support those requirements) were driven by the need to combat Soviet nuclear submarines in open ocean environments. The prevailing ASW strategy was designed to detect and prosecute enemy submarines at long ranges, and operations were most often conducted by single ASW units with minimal coordination with outside assets. The relatively benign deep ocean environment and nearly exclusive focus on the Soviet threat resulted in the development of effective and well practiced sensor and weapons tactics. ASW training mirrored that relatively narrow focus, and, combined with frequent real-world encounters, was quite effective in producing competent ASW operators and tacticians.

Conditions since the end of the Cold War, and those expected throughout the next decade, impose additional complexity on maintaining our ASW superiority. Russian nuclear submarine technology continues to improve and advanced submarines continue to be built and delivered to their fleet. Concurrently, the proliferation of improved diesel submarine technology to many Third World nations requires that our ASW forces also be capable of conducting operations in the vastly different littoral regions.

Littoral environments introduce added difficulty in optimally employing onboard sensors and weapons tactics. Coastal areas with shallow water, complex bathymetry and bottom topography, heavy shipping, and highly variable environmental conditions impose significant restrictions on traditional deep water tactics. The diesel submarine operating in home waters has the additional advantage of familiarity with environmental anomalies, slow speed operation, and support from own nation defense systems.

The training challenge has thus become two-fold; retaining the Cold War capability to detect and prosecute nuclear submarines while expanding our current capability against diesel submarines of the Third World. When coupled with dramatic reductions in ASW training resources, including at-sea training, this historic change compels the development of different approaches to training for both sensor operators and tacticians.

Traditional ASW Training

Sensor Operators. In the past, the ASW training has been based on a balance between schoolhouse and operational training. To become journey level operators, students learned the basics in schoolhouse training and then received extensive on-the-job training through supervised practice by experienced fleet crews at-sea. The schoolhouse training focused on memorizing facts, procedures, and large databases of threat intelligence parameters. Students were not taught to think about and relate the underlying physics of threats, the environment and the sensor systems. This approach resulted in graduates who could answer specific factual questions based on memorized information and who could perform procedures but who had difficulty in applying knowledge and principle to solve problems in operational situations. Great reliance was placed on a substantial

amount of at-sea experience to transfer the knowledge and skill gained in formal training to operational competency.

Tacticians. For years, frequent successful detection and encounters with Soviet submarines provided fleet tacticians the best kind of on-the-job training in ASW tactics. Schoolhouse tactical training was not extensive and focused on basic knowledge, procedures, and crew coordination. For example, classroom training typically emphasized the principles of oceanography and the effects of the ocean environment on sound transmission but provided little in depth practice in applying environmental information to tactical planning and mission execution. The development of tactical planning skills was acquired on-the-job. A recent study (Reynolds, Wetzel-Smith, Ellis, & Wulfeck, in press) of tacticians and pilots in the Maritime Patrol Aviation community examined the relationship between job conditions and tactical planning skills as measured by a scenario based planning skills test. The results showed that higher levels of work site training and technical support produced higher test scores. Officer ratings of the training received on the job and self proficiency ratings were also positively related to test scores. However, test scores were generally low. Mean scores for the highest performers were below 60 percent. In addition, the amount of operational experience reported was low and was not associated with test performance. This finding, in conjunction with the overall low scores found for the planning skills tests, indicates that current job conditions alone may not be adequate to support proficiency in tactical planning and mission execution.

Post Cold War ASW Training Requirements

There is now a broad consensus across all four ASW training communities that the combined change in threat, environment, and operating circumstances requires a new training approach.

Current fleet ASW practitioners receive little at-sea operational practice against non-cooperative submarines. As a result, an operators ability to detect, classify, and track submarine targets will be directly related to the quality of initial training, and to how well those skills are maintained and increased throughout a career. The same will be true for the tactician whose responsibility for planning and directing ASW missions requires a far more qualitative understanding of the environment, own and other systems and tactics, as well as target sensor capability, tactics, and weapon systems. To achieve this level of competence, the limited hours available for both schoolhouse and at-sea training must be used to provide both a solid conceptual understanding of the complex tasks that individuals and crews must perform as well as the opportunity to practice those tasks under varying real-world conditions.

Achieving these goals will require substantive changes in the execution of schoolhouse and operational training. ASW training in the 1990s must see dramatic modifications to passive acoustic analysis training and substantial expansion of training in active sonar, radar, and electromagnetic sensor systems to enable operators to contribute effectively in a multi-sensor approach to submarine prosecution. Further, the complexity of the acoustic environment in the littoral regions requires a substantial increase in knowledge of the effects of ocean bathymetry on acoustic energy transmission and how that, in turn, affects sensor selection and placement. These training requirements can only be met through principle-based application of training technologies, that can provide conceptual knowledge and high fidelity experience to offset the lack of at-sea practice.

The Interactive Multisensor Analysis Training (IMAT) System

Overview

The Interactive Multisensor Analysis Training (IMAT) system was developed to address post Cold War ASW training requirements. Specifically, IMAT is a classroom based approach to training that is designed to teach the complex conceptual knowledge and cognitive and procedural skills required to reason about the interrelationships among the operating modes of target submarines, the environmental variables that affect sound transmission, and the sensor systems used for detection and localization. In addition, IMAT provides extensive training on submarine acoustics and interpretation of sensor system data.

The IMAT approach to training is based on recent advances in cognitive psychology and instructional technology. It combines cognitive analytic and instructional design technology with advanced computer-based graphics and programming technology. The result is a dynamic graphical interface integrated with state-of-the-art instructor and student guides, which provides the traditional classroom instructor with a capability to effectively teach complex cognitive concepts and skills. In the past, achieving this capability has been hampered by limitations in cognitive task analysis, and particularly in cognitive models. In addition, limitations in computer capabilities have precluded the development of cause and effect representations of highly complex, multi-modal tasks that are required of expert practitioners. Recent developments in cognitively-based training design have demonstrated that models of physical phenomena can be integrated with high resolution graphics to demonstrate the interactive relationships of threat, environment, and system for operator training, and interactions of multiple sensor systems for tactician training. The IMAT system extends that technology in the traditional classroom environment, with specific emphasis on cognitive design models that account for knowledge structure interrelationships, to provide cause and effect training for decision making with multiple system input, and to allow visualization of interactive spatial relationships among operators, sensors, and other platforms.

Specifically, for sensor operators, IMAT apprentice training is presented in a mission context with a substantial emphasis on the interactive relationship among environmental factors, threat behavior, and sensor system capabilities and constraints. Because sensor operators at the apprentice level have limited backgrounds in submarine operations, the physics underlying energy transmission, and in operating complex sensor systems, establishing a good conceptual understanding of the complicated interactions that occur in the real world is the essential foundation for learning effective sensor operation. Students are taught to understand that the enemy submarines mission will largely dictate its operating mode including course, speed, and depth of operation, and that the operating mode of the submarine defines its vulnerabilities to onboard acoustic and electromagnetic sensors. They are further taught how the relative complexity of the ocean environment will impact detection ranges, search rates, and contact duration. Students learn to reason through these interactions in a cause and effect learning process. Multi-dimensional interactions are displayed visually and the IMAT instruction provides qualitative explanations for the interactions that occur. IMAT presents demonstrations of varying outcomes based upon changes in the threat or environment to promote the development of the principle-based knowledge critical for adaptations to the variations presented in real world situations. Finally, tests of student proficiency for IMAT training include questions that require problem solving and understanding causal relationships in addition to the traditional fact recognition and procedural process items.

IMAT training for tacticians is similar to the training for sensor operators. Establishing a good conceptual understanding of the complicated interactions that occur in the real world is an essential foundation for learning effective platform and sensor employment. Therefore, IMAT presents tactical training in a mission context with a substantial emphasis on the interactive relationships among environmental factors, threat behavior, and sensor system capabilities and constraints. Although applied to different task responsibilities than the sensor operators, these critical relationships form the basis for developing tactical skills. Like operators, IMAT trained tacticians are taught to understand that the submarine's mission will largely dictate its operating mode, including courses, speeds, and depths of operation and the operating mode of the submarine makes it vulnerable to detection by onboard sensors and which are best suited for employment. IMAT elaborates how the relative complexity of the ocean and/or atmospheric environment impacts detection ranges, search rates, and anticipated contact duration, and then teach tacticians the knowledge required to employ their platforms and direct their combat sensor teams to optimize search rates and probabilities of detection within both temporal and search area constraints. As in operator training, IMAT teaches tacticians how to reason through these interactions in a cause and effect learning process using displays that demonstrate multi-dimensional interactions with varying outcomes visually. IMAT instruction provides qualitative explanations for interactions that occur with the goal of developing principle-based knowledge critical for adapting to the various real world situations. Proficiency assessment for tacticians includes tactical scenario problems as well as facts and causal relationship questions.

Research Background

The IMAT system integrates several areas of research on cognition and instruction, including, graphical techniques to promote visualization of invisible phenomena in science teaching, elaborated explanations, contextualized or anchored instruction, and instructional sequencing. The following sections briefly summarize portions of this work.

Scientific Visualization. Scientific visualization has traditionally been used by scientists to explore phenomena and to communicate with other scientists (Bryson, 1994). When used for presentations, researchers select data sets, transform them, and then turn them over to specialized graphic artists to develop images and animation. However, the end products of this process have not been designed for laymen or students. IMAT aims to bring this technology into specialized technical training.

Research support for scientific visualization as a training strategy comes from the literature on instructional media. Both static and dynamic graphic displays have been shown to facilitate teaching of scientific concepts (Baek & Layne, 1988; Dwyer, 1972; Gropper, 1966; Lumsdaine, Sulzer, & Kopstein, 1961; Rieber, 1990; Rigney & Lutz, 1975; Park & Gittelman, 1992; Wetzel, Radtke, & Stern, 1994); Levie and Lentz (1982) in a meta-analysis of illustrated text studies concluded that learning and retention is facilitated by illustrations, if the illustrations are directly related to the text. Park and Gittelman (1992) found that subjects trained with dynamic graphics performed better on electronic troubleshooting problems than those trained with static displays. White (1984) used animated computer graphics to successfully teach the basic principles of Newtonian laws of motion and force. IMAT employs a computer based graphical interface to conceptual models of real world phenomena to deliver both static and dynamic graphics in a traditional classroom environment.

Elaborated Explanations. Providing students with elaborated explanations, analogies, etc. about how and why systems, events, and phenomena are structured and function has been shown to facilitate learning and retention. Research on learning skills and learning from text has shown that elaborated explanations enhance the students mental models and increase retention (Konoske & Ellis, 1991; Mayer, 1989; Smith & Goodman, 1982). In a series of studies of learning from scientific text, Mayer (1989) found that providing students with a conceptual model increased learning, retention and transfer. The conceptual models in his instruction used both text and diagrams to highlight major objects and actions and the causal relations among them. That is, the models focused on how and why systems work. Smith and Goodman (1982) studied the effects of providing elaborated instructions on learning and performing a procedural assembly task and found that instructions containing functional information resulted in fewer errors. Swezey, Perez, and Allen (1991), in a study on transfer of electromechanical troubleshooting skill, found that some level of generic structure and functional knowledge is required for cross domain transfer. The IMAT system uses elaborated explanations throughout the instruction to (1) clarify complex relationships such as those among water temperature, pressure and depth, and salinity; (2) provide comprehensive feedback for practice exercises; and (3) describe graphically displayed examples.

Contextualized Instruction and Instructional Sequencing. Contextualized or job oriented instruction has been found to be more effective in learning, retention, and performance than topic oriented instruction (Cognition & Technology Group at Vanderbilt, 1990; Collins, Brown, & Newman, 1989; Goffard, Heimstra, Beecroft, & Oppenshaw, 1960; Johnson, 1951; Semb & Ellis, 1994; Shoemaker, 1960; Steinemann, Harrigan, & VanMatre, 1967;). Further, within a job context, mental model development is facilitated by teaching students to reason about events and phenomena that involve several interrelated variables. Proper sequencing may play an important role in cognitive skill development. While early research on sequencing showed that with simplified or isolated tasks, different sequences of instructional events made little difference, more recent research and theory suggests that for complex tasks, sequencing strategies may have significant effects. For example, Reigeluth and Stein (1983) argues that beginning instruction with a condensed holistic overview of a task domain leads to better learning than more traditional sequences, which teach isolated topics first and integrate them later. More recently, extreme constructivist approaches to instruction (e.g. Duffy & Jonassen, 1991) argue that learners should sink-or-swim in a fully elaborated domain. Merrill, Li, & Jones (1990) also argue for a holistic approach to teaching complex domains, but include moderate structure and sequencing recommendations in their approach. Drawing from Reigeluth and Stein (1983), IMAT begins with a simplified overview of target, environment, and sensor system relationships in the context of the jobs and tasks performed by operators and tacticians. This context is revisited throughout IMAT to reinforce the reality that students are learning to do a job, not memorize a list of topically related facts.

Research Questions

In each of these areas, little experimental work has been done on the extent to which the findings are generalizable to instruction delivered using simulation- and graphical-interface-based training technologies. Furthermore, there are almost no larger efforts that evaluate the integration of these approaches into an overall strategy. The current effort tests the hypothesis that the IMAT system, which represents an integrated combination of these approaches, offers a potent learning

environment for promoting acquisition of the complex knowledge and skills involved in sensor-system operation and tactical planning. Specifically, this report documents the implementation and evaluation of the IMAT system in the Sonar Technician Surface (STG) "A" School at the Fleet Antisubmarine Warfare Training Center Pacific in San Diego (sensor operators) and the Tactical Training Course (TTC) at the Fleet Aviation Specialized Operations Training Group Pacific at Barbers Point (tacticians). These two IMAT applications are described in the following sections followed by the specific research objectives for this effort. The description of the STG "A" school application includes a review of the first IMAT implementation and evaluation in the Aviation Antisubmarine Warfare Operator (AW) "A" school in Millington (Ellis & Parchman, 1994) because data from this school are compared with STG "A" data in the present evaluation.

Sensor Operators--AW "A" and STG "A" Schools. The first IMAT classroom implementation was in the AW "A" school at Naval Air Technical Training Center, Millington, TN. IMAT replaced the existing oceanography unit in the "A" school curriculum. Although the basic classroom configuration and environment were not altered, the IMAT unit represented a significant change from the existing instruction. The unit length was increased from 26 to 58 class periods and there were extensive changes in both the instructor and student guides, which were redesigned using IMAT criteria to provide both elaborated explanations and more contextualization. Furthermore, the IMAT graphical interface was used to provide the classroom instructor with both static and dynamic displays of a important concepts and relationships including, sound transmission paths, water column characteristics, target motion, and sound propagation. All of these changes resulted in a course that emphasized learning cognitive skills and complex relationships instead of memorizing factual information, which was the focus of the existing unit. A formative evaluation of this application (Ellis & Parchman, 1994) found increased motivation for IMAT students but revealed significant problems with the unit test, which limited the assessment of performance differences. The unit test for the IMAT instruction was very similar to the test for the oceanography unit that IMAT replaced. The formative evaluation showed that many IMAT objectives were not tested. Further, the previous course test items, included in the IMAT unit test, tested factual knowledge but, did not test the cognitive concepts and skills that IMAT was designed to teach. Thus, while the results of the performance assessment showed that IMAT students performed as well as previous course students on the factual items common to both tests, it was not possible to compare student performance on the more complex knowledge and skills. As a result of the formative evaluation the AW "A" school IMAT unit test on oceanography was extensively revised. The revised test replaced the fact-based test in the AW "A" school and was also used as the primary evaluation instrument in the STG "A" school IMAT. This allowed comparisons between AW and STG IMAT students.

The AW "A" school IMAT oceanography unit was adapted for implementation in the STG "A" school. The STG "A" revision was not as extensive as the AW "A" schools. Because of course length constraints, the number of class periods (26) was not increased for the revised course. Several topics were eliminated because they were either not relevant to the STG rating or were taught in other sections of the course. The STG instructor guide was completely revised using the AW instructor guide as a basis and the STG student guide was augmented by adding portions of the AW student guide. During instruction, the IMAT trainer was used by the classroom instructor in the same way it was used in the AW unit. The STG end of unit test was comprised of relevant items from the AW end of unit test.

Tacticians--Tactical Training Course (TTC). The Tactical Training Course (TTC) was developed to provide qualified Patrol Plane Naval Communicators and Patrol Plane Second Pilots with the tactical knowledge and skills needed to perform Tactical Coordinating Officer (TACCO) and Patrol Plane Commander (PPC) responsibilities. The TTC was a new course and did not replace any existing classroom instruction. The course emphasizes tactical oceanography and practical on-station application of tactics. The IMAT trainer provided the classroom instructor in the TTC with the same capabilities as were provided in the AW "A" and STG "A" units. The TTC is intended to bridge the gap between basic Fleet Replacement Squadron training and the graduate level Tactical Training Team course. It is one of five requisite courses for fulfilling the requirements to become a PQS qualified TACCO or PPC.

Objectives

The objectives of this effort are (1) to evaluate the application of the IMAT system in the STG "A" school with respect to performance on factual, comprehension, and cognitive skill test items, student motivation, and instructional design; (2) to compare student performance on STG "A" IMAT lessons with student performance on comparable Aviation Systems Warfare Operator (AW) "A" school IMAT lessons; (3) to evaluate application of the IMAT system in the TTC at Barbers Point; and (4) to compare graduates of the IMAT TTC with qualified fleet tactical officers and pilots on tests of knowledge of acoustical oceanography and tactical problem solving.

Method

STG "A" School Evaluation

Design

The STG "A" IMAT application was evaluated on (1) student performance on three types of end of unit test items (fact items, comprehension items, and cognitive skill items), (2) student motivation, and (3) quality of instructional design. STG students trained with the IMAT system were compared with STG students trained with the conventional instruction used in the "A" school prior to the introduction of IMAT, and with students from the AW "A" who had also been trained with the IMAT system.

Subjects

The subjects were 90 students who had completed the STG "A" school oceanography unit prior to the introduction of the IMAT system (the Standard Instruction group), 71 students who were taught the same unit with IMAT (the IMAT group), and 46 students who completed the IMAT oceanography unit at the AW "A" school (the AW IMAT group). Although ASVAB scores were not available because of privacy act considerations, the STG and AW "A" schools have almost identical ASVAB entry requirements. Therefore, the student samples from the two schools were considered to be equivalent in ability.

Instructional Materials

The instructional unit for all three groups taught acoustical oceanography and all groups were compared on identical end of unit test items. The major topics addressed in all three units were environmental factors affecting underwater sound transmission, bathythermic and sound velocity profiles, sound transmission paths including ray path theory, and attenuation and spreading.

Standard Instruction. The number of learning objectives for the Standard Instruction is five which are taught in 26 class periods (approximately 4 and a half days including testing time). The instructor guide is 20 pages long and the student guide consists of 30 pages. The instruction is topic oriented rather than teaching the knowledge and skills in a job context. The graphics are 135 slides and a video tape on the deep scattering layer. Neither the instructor guide nor the student provide any opportunities for practice in preparation for taking the unit test.

STG IMAT Instruction. The number of objectives and unit length for the STG IMAT instruction are the same as for the Standard Instruction. The instructor guide is 50 pages long and 20 pages of practice exercises (31 problems) were added to the Standard Instruction 30 page student guide. The instruction is presented in the context of the job of detecting and tracking submarine targets under a variety of environmental conditions. The graphics are 193 IMAT displays and 19 slides/overheads.

AW IMAT Instruction. The number of objectives for the portions of the AW unit used for the comparison is 59 and the length is 39 class periods (approximately 6 and a half days including testing time). The instructor guide is 205 pages long and the student guide is 190 pages long and includes practice for each of the objectives. The instruction is highly contextualized. The graphics are 193 IMAT displays and 17 overheads.

End of Unit Test

After completing their respective oceanography units, students were given an end of unit test, which included items that could be used to compare the effects of STG-IMAT, AW-IMAT, and Standard Instruction. The test items were classified into one of the following categories according to the type of information tested and the cognitive processing required to answer the question:

Remember Fact. The student must recall or recognize names, definitions, steps of procedures, formulas and terms in formulas, labels for graphical display, or technical terminology.

Remember Qualitative Information (Comprehension). The student must recall or recognize cause and effect relationships, predictive and diagnostic information, or how and why explanations of events (e.g., diurnal effect), phenomena (e.g., bottom bounce), and devices (e.g., sensors).

Cognitive Skills. The student must perform a sequence of steps, including making decisions and judgments, to solve a problem, calculate or determine a value or relationship, or evaluate a scenario.

The test items used for the evaluation were 32 Fact items, 15 Qualitative Information/Comprehension items, and 16 Cognitive Skill items. These test items were selected from a pool of test items developed for testing oceanography knowledge and skills. All test items in the pool were reviewed by STG "A" and AW "A" course instructor personnel and by subject matter experts assigned to the IMAT project. Items that were rated beyond the scope of the instruction or inappropriate for "A" school training were eliminated. From the remaining items, the 63 used in this evaluation were selected based on their match to the STG "A" and AW "A" oceanography unit objectives. Figure 1 displays an example of each type of item.

Example Fact Item

Sound Channel is important to ASW because:

- a. all sounds in the Sound Channel portion of the water column get trapped for long distances
- b. the number of sounds trapped in the Sound Channel increase to the Limiting Depth
- c. limiting rays near the top of the Sound Channel define shadow zones submarines use to avoid detection
- d. the top of the Sound Channel traps more sounds than the Sound Channel Axis

Example Comprehension Item

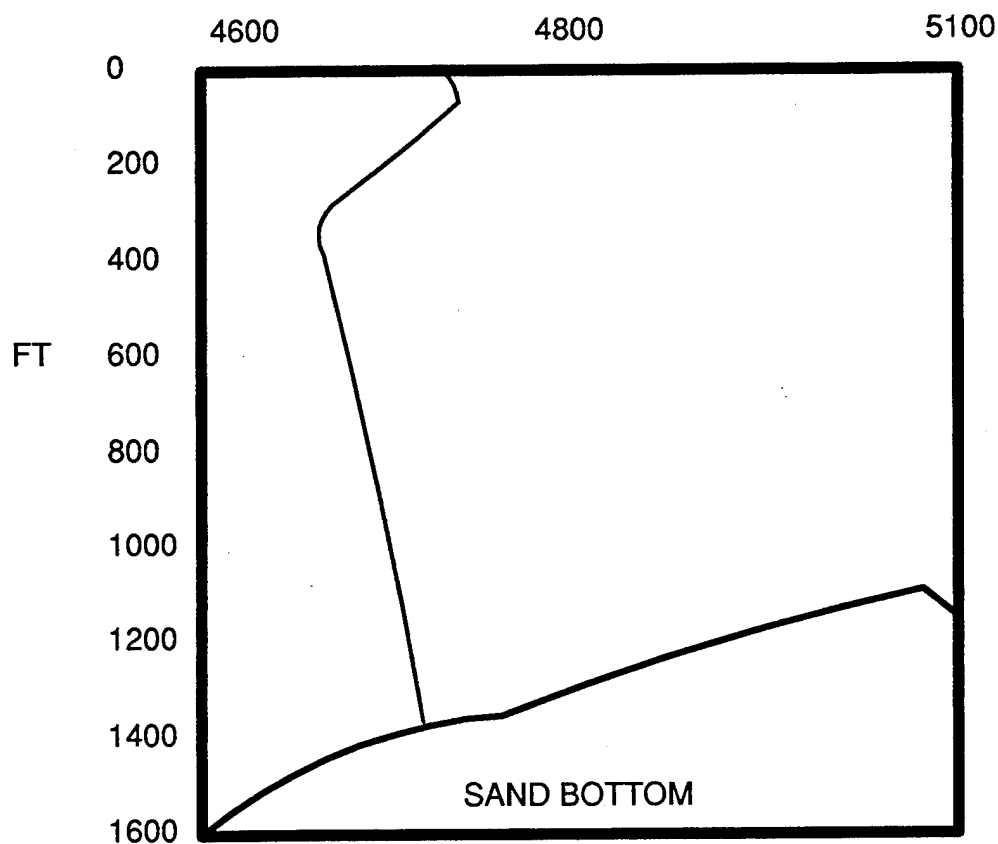
The probability of CZ decreases when maximum near-surface velocity:

- a. adjusts to a cooler surface layer
- b. decreases
- c. lowers the limiting depth
- d. occurs higher in the water column

Figure 1. Example test items.

Example Cognitive Skill Item

Look at the following SVP and ocean description. Note that depth is indicated in feet. Which sound transmission paths are possible for this water column with these environmental characteristics? Answer the questions by selecting "T" to indicate possible transmission paths and the letter "F" for paths that are not possible.



Sea state:	2
Shipping intensity	low

- _____ Bottom Bounce (BB)
- _____ Convergence Zone (CZ)
- _____ Direct Path (DP)
- _____ Half Channel (HC)
- _____ Sound Channel (SC)
- _____ Surface Duct (SD)

Figure 1. (Continued).

Motivational Analyses

For the motivational analysis a questionnaire based on the Attention-Relevance-Confidence-Satisfaction (ARCS) motivational assessment model originated by Keller (1992) was developed. The 34 item questionnaire, designed for application to technical training, was administered to all of the 71 STG "A" school IMAT students. Unfortunately, the motivation questionnaires for the Standard Instruction students were either not collected or were lost in transit and could not be analyzed. In a previous study (Ellis & Parchman, 1994), the ARCS questionnaire was administered to 76 AW "A" school students trained with the IMAT system. These data were used in the present evaluation for comparison. The ARCS questionnaire assess four motivational characteristics; attention, confidence, relevance, and satisfaction. The attention oriented questions assess how well the material captures the interest of the learners and stimulates their curiosity to learn. The relevance questions address how well the materials meet the needs and goals of the learner. The confidence questions ask the students to report on their beliefs and feelings about how well they will succeed and how much they can control their own success. The satisfaction questions concern students feelings of reward and accomplishment and their enjoyment of the materials. The four scales are scored from 1 to 5 with 1 indicating a statement about the course is "Not true" and a 5 indicating a statement is "Very true." A score of 3 indicates students believe a statement is "Moderately true."

Instructional Design Evaluation

The Course Evaluation System (CES) (Ellis, Knirk, Taylor, & McDonald, 1993) was used to compare the instructional design of the IMAT and Standard Instruction oceanography units. In a previous study (Ellis & Parchman, 1994), the CES was used to evaluate the AW "A" IMAT unit. Relevant portions of these data were used for comparisons with the STG units in the present evaluation. The CES assesses the consistency (match) among learning objectives, test items, and the instructional presentation, and the adequacy of the instructional presentation. For the present evaluation, however, the objectives and test items for the two STG units were identical. For the AW unit, the objectives were different but the test items were identical. Therefore, the CES was used to assess the consistency among the test items and the instructional presentations for each unit. The consistency assessments were then compared for the evaluation. The consistency assessment employed the same classification scheme for test items used for the end of unit test.

Tactical Training Course Evaluation

Design

For the TTC evaluation students were administered a paper and pencil knowledge and cognitive skills test upon entering the school and after completing the course in a standard pre-post design. The scores of TTC graduates were also compared with the performance of qualified fleet tacticians and pilots on the same testing instrument.

Subjects

Subjects were 59 non-Personnel Qualification System (PQS) qualified officers who were selected to enroll in the TTC course. Of this group 26 were tacticians and 33 were pilots. The fleet comparison subjects were 21 PQS qualified officers. Of this group 9 were TACCOs and 12 were PPCs.

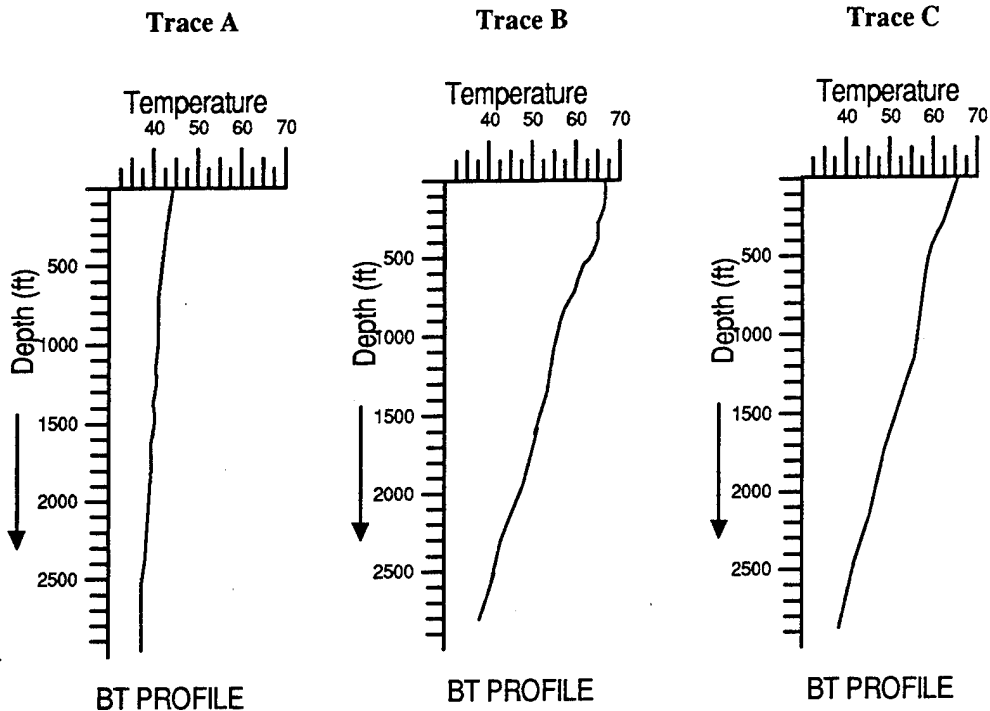
Instructional Materials

The TTC is a 10 day course in which tactical oceanography is one of several topics. The number of learning objectives for the tactical oceanography portion of TTC course is 19, which are taught over 8 and a half class periods spread over 3 instructional days. The instructor guide is 40 pages long and the student notebook is 42 pages. The instruction is presented in the context of the job of locating, tracking, and prosecuting submarine targets under a variety of environmental conditions and tactical situations. The graphics are 120 IMAT displays.

Pre- and Post-Course Tests and Testing Procedures

The pre- and post-course tests were designed to assess application of environmental principles and tactical planning. Two parallel forms of the test were developed for the pre-post design. The pretest contained 17 knowledge question that included both fact and comprehension items and 7 scenario problems that tested cognitive skills. The posttest contained 16 different knowledge questions and the same 7 scenario problems that were on the pretest. Figure 2 presents a sample scenario problem. All test items were reviewed and validated by subject matter specialists. The pretest was given to students prior to taking the TTC course. The posttest was given to students upon completion of the tactical oceanography portion of the course and also to the qualified fleet pilots and tacticians. In addition, all subjects were given a demographic questionnaire to determine years of experience, years of PQS qualification (for fleet personnel), age, and years in service.

You are on deployment in Adak, Alaska, in the winter. Your first task to search, localize and track an SSBN operating in the North Pacific



Which of the above BT traces (trace A, trace B, or trace C) would you expect to find around 60 North Latitude (in your operating area), in the winter? Answer: BT Trace _____

Draw the Sound Speed Profile that corresponds to the BT Trace that you selected and Label your SSP drawing with the sound transmission pathways (i.e., surface duct, deep sound channel, etc.)

Your Sound Speed Profile

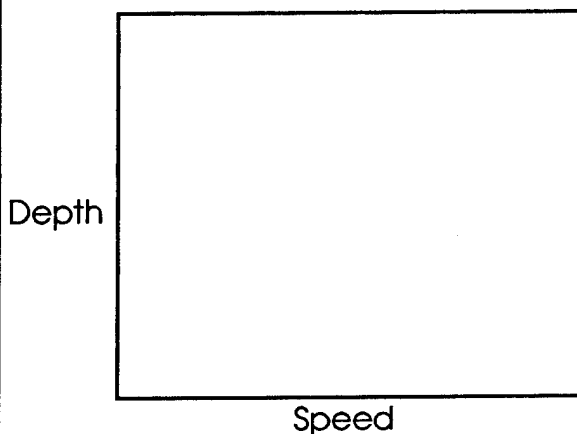


Figure 2. Sample scenario-based problem.

Results and Discussion

STG "A" School Evaluation

End of Unit Test Analyses

A 3 Groups (STG Standard Instruction vs. STG IMAT vs. AW IMAT) by 3 Item Type (Fact vs. Comprehension vs. Cognitive Skill) analysis of variance (ANOVA) was performed on percent correct for each type of item on the end of unit test. Table 1 presents the means for this analysis. Both main effects and the Groups by Item Type interaction were significant ($p < .01$). Post hoc Tukey HSD comparisons revealed that AW IMAT students scored higher on all item types than the other two groups ($p < .05$). Further, the STG IMAT students scored higher on all item types than the STG Standard Instruction students ($p < .05$). The significant interaction was attributable to students in both the IMAT groups scoring relatively better on Cognitive Skill and Comprehension items compared to Fact items than Standard Instruction students ($p < .05$).

Table 1

Mean Percent Correct for Fact, Comprehension, and Cognitive Skill Test Items for STG-IMAT, AW-IMAT, and Standard Instruction Groups

	Facts (%) <i>N</i> = 32 Items	Comprehension (%) <i>N</i> = 15 Items	Cognitive Skills (%) <i>N</i> = 16 Items	Total (%) <i>N</i> = 63 Items
STG Standard Instruction <i>N</i> = 90	79.5	63.2	62.4	71.3
STG IMAT <i>N</i> = 71	89.0	76.0	77.2	82.9
AW IMAT <i>N</i> = 46	94.9	87.8	83.8	90.4

The finding that IMAT students performed better on all three types of test items supports the hypothesis that the combination of strategies incorporated in the IMAT system provides an effective environment for learning complex knowledge and skills. The most important result for the hypothesis is that both STG- and AW-IMAT students performed better on Comprehension and Cognitive Skill items relative to Fact items than the Standard Instruction students. That is, the significant Groups by Item Type interaction shows that the IMAT system differentially increased learning and performance for the more complex types of items. This result is exactly what IMAT was designed to accomplish and directly addresses the post Cold War training requirements for sensor operators.

Instructional Design Analyses

The significant differences among the three groups on the three types of test items can in part be explained by comparing the degree to which some of the fundamental instructional principles underlying the IMAT system were applied in each unit. The results of the CES analysis reveals

some of these differences. First, the total number of objectives for the AW-IMAT unit was 59 versus 5 for the STG units (remember that course length and objectives did not change for the STG IMAT application). Second, the AW unit length was 39 class periods versus 26 for the STG units. For the AW unit, 33 objectives were Fact, 19 were Comprehension, and 7 were Cognitive Skill. For the STG units four objectives were Fact, one was Cognitive Skill, and none were Comprehension. Third, the number of graphic displays increased by nearly 50 percent for both IMAT groups.

The differences in length and number and type objectives result in part from the AW-IMAT unit being completely redesigned, while the STG-IMAT unit was only modified to accommodate IMAT. The AW-IMAT redesign reflects a thorough front-end analysis of the knowledge and skills that are required for proficiency and a concern for teaching the cognitive concepts and relationships needed to reason in a complex environment. These major differences in unit length, number and type of objectives, depth of analysis, and training emphasis probably all work to improve the performance of AW-IMAT students. Additionally, the increased number of displays and the accompanying contextualized elaborated explanations may have contributed to the difference between the two STG groups. However, the increase in displays alone does not account for the performance differences between AW- and STG-IMAT students as the displays used in each unit were identical ($n = 193$). In the AW course the displays were more highly integrated with the elaborated examples and practice than in the STG IMAT course, which only incorporated portions of the AW student and instructor guides. Thus, the combined effects of the displays and accompanying instructional approach could have produced the performance differences.

Although performance improvements were predicted for the IMAT groups, the increased performance on Fact items for both IMAT groups compared to the Standard Instruction group shows a benefit for IMAT training that was not observed in the results of the Ellis and Parchman (1994) evaluation of the AW-IMAT unit. They found no differences between AW-IMAT students and AW previous unit (standard instruction) students on comparable multiple-choice items that tested factual information. This discrepancy can be accounted for by examining the opportunities for practice in each unit. The AW-IMAT, AW previous, and STG-IMAT units all provided some practice opportunities for the Fact objectives, while the STG Standard Instruction had no such opportunities. Further, the AW-IMAT provided more opportunities for Fact practice than the STG-IMAT. Practice opportunities may also in part account for the differences between STG-IMAT and Standard Instruction students on Comprehension and Cognitive Skill items. Again, there was no practice for Standard Instruction students while 31 problems that included practice on all three types of items were added to the STG-IMAT unit (see Table 2).

The CES evaluation of the consistency among instructor and students guides and the test items also reveals differences among the three units that may account for the performance differences. Table 2 shows percent of instructional components that are present in the instructor and student guides for each type of test item for each unit. For example, if there were 10 Fact test items, each item would require a statement and an opportunity to practice remembering to be present somewhere in the instructor or student guides. If there were only five statements and three practice questions for the 10 Fact items, the percentages in the Statement and Practice Remembering w/ Feedback columns would be 50% and 30%, respectively. (Note that for Fact and Comprehension items the Example and Practice Using components are not required). In the AW IMAT course all

required components are present, while components are present to a lesser degree for the two STG units. In the STG Standard Instruction, the practice component for all three categories of test item is not present at all. This more detailed analysis confirms the general analysis of practice opportunities just discussed. The absence of practice and other required instructional components for specific test items in the Standard Instruction and to a lesser degree in the STG-IMAT instruction may account for some of the performance differences among the three groups.

Table 2

Percent of Each Required Presentation Component that is Present for Each Type of Test Item for the STG-IMAT, AW-IMAT, and Standard Instruction Units

Test Item Type and Instructional Unit	Statement	Required Presentation Components		
		Practice Remembering w/Feedback	Examples	Practice Using w/Feedback
Fact (<i>N</i> = 32)				
Standard Instruction	75.0	0.0	NA	NA
STG-IMAT	90.6	18.6	NA	NA
AW-IMAT	100.0	100.0	NA	NA
Comprehension (<i>N</i> = 15)				
Standard Instruction	66.7	0.0	NA	NA
STG-IMAT	100.0	40.0	NA	NA
AW-IMAT	100.0	100.0	NA	NA
Cognitive Skill (<i>N</i> = 16)				
Standard Instruction	12.5	0.0	6.3	0.0
STG-IMAT	37.5	87.5	100.0	87.5
AW-IMAT	100.0	100.0	100.0	100.0

Motivational Analysis

The ARCS questionnaire assesses four motivational characteristics; attention, confidence, relevance, and satisfaction. Each characteristic is rated from one to five; not true to very true, respectively. The mean scores for each scale for the STG-IMAT unit are: Attention = 3.38, Confidence = 3.77, Relevance = 3.79, and Satisfaction = 3.47. These scores are not significantly different from the ARCS scores for AW "A" IMAT students collected in a previous study (Ellis & Parchman, 1994). The AW scores were Attention = 3.43, Confidence = 3.35, Relevance = 3.76, and Satisfaction = 3.49. As reported in Ellis and Parchman (1994), motivation scores in the ranges obtained in both the AW and STG IMAT units are significantly higher than scores obtained for both standard instruction and specially designed individualized computer based training in an introductory electricity course.

Tactical Training Course Evaluation

Pre-Post Analysis

Scores for pilots and tacticians on the pre and posttests for the knowledge and scenario test items were compared using t-tests. There were significant gains from pretest to posttest for both types of items for both pilots and tacticians ($p < .01$). Table 3 presents the mean percent correct for the knowledge and scenario items for pilots and tacticians. This result shows that the IMAT system was effective in achieving the course goals.

Table 3

**Mean Percent Correct for Knowledge and Scenario Items on the
TTC Pre- and Posttest for Pilot and Tacticians**

	Pretest	Posttest
Knowledge Items		
Tacticians	55.4	81.6
Pilots	47.9	82.0
Scenario Items		
Tacticians	54.7	78.3
Pilots	48.2	76.7
Totals		
Tacticians	55.1	79.7
Pilots	47.4	78.2

Fleet Comparison Analysis

A 2 job category (pilot vs. tactician) by 2 item type (scenario vs. knowledge) by 2 experience (TTC graduate vs. PQS qualified) ANOVA was performed on the scores on the knowledge and scenario items on the TTC end of course test. The only significant difference was for experience with TTC graduates scoring higher than PQS qualified fleet personnel on both scenario and knowledge items. Table 4 presents the means for this analysis. The finding that TTC students score higher than fleet qualified personnel shows that IMAT can accelerate the development of expertise on job relevant scenarios as well as provide an effective cognitive context for assimilating job knowledge. Retesting of TTC graduates is planned after they are PQS qualified to determine the long term effects of IMAT training.

Table 4

**Mean Percent Correct for Knowledge and Scenario Items for
TTC and Fleet Qualified Pilots and Tacticians**

	TTC Graduates	PQS Qualified Fleet Personnel
Knowledge Items		
Tacticians	81.6	72.9
Pilots	82.0	71.9
Scenario Items		
Tacticians	78.3	73.8
Pilots	76.7	69.6
Totals		
Tacticians	79.7	73.5
Pilots	78.2	70.4

Conclusions

Several conclusions can be drawn from these evaluations. First, research on cognition and instruction and technological advances in scientific visualization can be integrated and applied in real world training to produce substantial gains in performance and student motivation. Second, the IMAT system has achieved its intended design goals by effectively teaching complex knowledge and cognitive skills. Third, the IMAT system emphasis on inclusion of required instructional components, especially practice opportunities, contributed significantly to the observed performance improvements. Finally, the TTC findings show that IMAT can accelerate the development of expertise in tactical oceanography and decision making. Overall, the results of the STG and TTC implementations show that IMAT is a highly effective training system that offers a viable solution for many of the training requirements and challenges faced by the four ASW communities in the post Cold War world.

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